November 1999

WIND RIVER WATERSHED PROJECT

Volume III of III

Annual Report 1998

DOE/BP-09728-3

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do not necessarily represent the views of BPA.

This document should be cited as follows:

Connolly, Patrick J. - US Geological Survey Columbia River Research Laboratory, 1999, Wind River Watershed Project 1998 Annual Report to Bonneville Power Administration, Portland, OR, Contract No. 98AI09728, Project No. 9801900, 35 electronic pages (BPA Report DOE/BP-09728-3)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

Please include title, author, and DOE/BP number in the request.

Wind River Watershed Project

1998 Annual Report

Volume III

November 1999

Prepared by:

Kenneth Wieman

USDA Forest Service
Gifford Pinchot National Forest
Wind River Work & Information Center
121 Hemlock Road
Carson, WA 98610

Prepared for:

Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project Number: 9054
Contract Number: 98 AI 09728

Volume III

Contents

Report H: Hemlock Dam Assessment and Restoration Options

Wind River Watershed Project

1998 Annual Report

January 1999

Kenneth Wieman

USDA Forest Service
121 Hemlock Road
Carson, WA 98610

Prepared for:

Bonneville Power Administration
Environment, Fish and Wildlife
P.O. Box 3621
Portland, OR 97208-3621

Project Number: 9054
Contract Number: 98 AI 09728

Hemlock Dam Fish Passage Evaluation and Restoration

Acknowledgements

I would like to than recognize the Department of Civil and Environmental Engineering at Washington State University who prepared the *Hemlock Dam Fish Passage Evaluation and Restoration* from which this summary report is taken. Specifically, I would like to thank Dr. Michael Barber for his guidance and professionalism. Ted Perkins deserves recognition for far too many things to mention; but, not the least of which include his diligence and perseverance while working under and extremely short timeline and capably responding to a wide array of critics. This document has also benefited from the many reviewers of involved in the process. Because of their comments and concerns, this document contains a cross section of interests and represents the position of many viewpoints. Among the reviewers I would like to thank: Dan Shively, Bob Yoder, Vicky Maggiora, Dave Heller, Mary Gibson, Brain Bair, Julie Knutson, Mary Bean, Woody Starr, Helen Rueda, Al Mateko, Earl Ford, and Neil Oliver with the USDA Forest Service; Dan Rawding with the Washington Department of Fish and Wildlife; Ed Meyer with the National Marine Fisheries Service; Pat Connolly and Ian Jezorek with the US Geological Survey; Lee Carlson and Paul Ward with the Yakama National; Tim Cummings with the US Fish and Wildlife Service; and Al McKee and Harpret Sandu with Skamania County. I would also like to thank John Baugher and the Bonneville Power Administration for providing the funding to complete this project.

Abstract

The objective of this study was to assess fish passage at Trout Creek's Hemlock Dam and prescribe options for restoring fish passage. We relied on existing field data, along with modeling techniques, and literature review to evaluate passage. The assessment notes that Trout Creek is historically important to production of wild steelhead (*Oncorhynchus mykiss*) in the Wind River. Restoration conservation scientists and engineers have been actively working on watershed restoration in Trout Creek for nearly two decades. Hemlock Dam is identified as a factor for decline of wild steelhead trout in the Wind River. Our evaluation identified several key concerns that are direct source of mortality and/or impediments to safe and efficient fish passage of migrants including; ineffective flow conditions, outdated ladder design, and dam fishway and trap operation. An array of the options for restoring fish passage were proposed which involve partial removal of the dam, replacing the fish ladder, replacing the fish screen, redesigning the fish channel and full removal of the dam. A detailed work plan and activity schedule identified a timeline and resources needed to implement each prospective restoration option. A benefit -cost analysis measured the value of expected fish returns against the implementation and operating cost of three options. The economic assessment clearly identified full dam removal as the most cost-effective measure in the

long term. The full dam removal option addresses all of the fish passage concerns assessed in this study.

Introduction

This study of fish passage at Hemlock Dam compiles known information about Trout Creek steelhead, assesses the risks to steelhead survival, and recommends options to restore fish passage at Trout Creek. This paper is a synopsis of the comprehensive study completed by the Civil and Environmental Engineering Department at Washington State University and USDA Forest Service (2000). A copy of the entire *Hemlock Dam Fish Passage Evaluation and Restoration* report is available from the Gifford Pinchot National Forest.

Location

Hemlock Dam is located at the administrative site of the Wind River Ranger Station and former Nursery (Section 27, T.4.N., R.7 E. Willamette Meridian). The dam is positioned at river mile (RM) 2.0 on Trout Creek, a tributary to the Wind River near Carson, Washington (Figure 1).   The Wind River flows to the Lower Columbia River entering the Bonneville pool at RM 154.

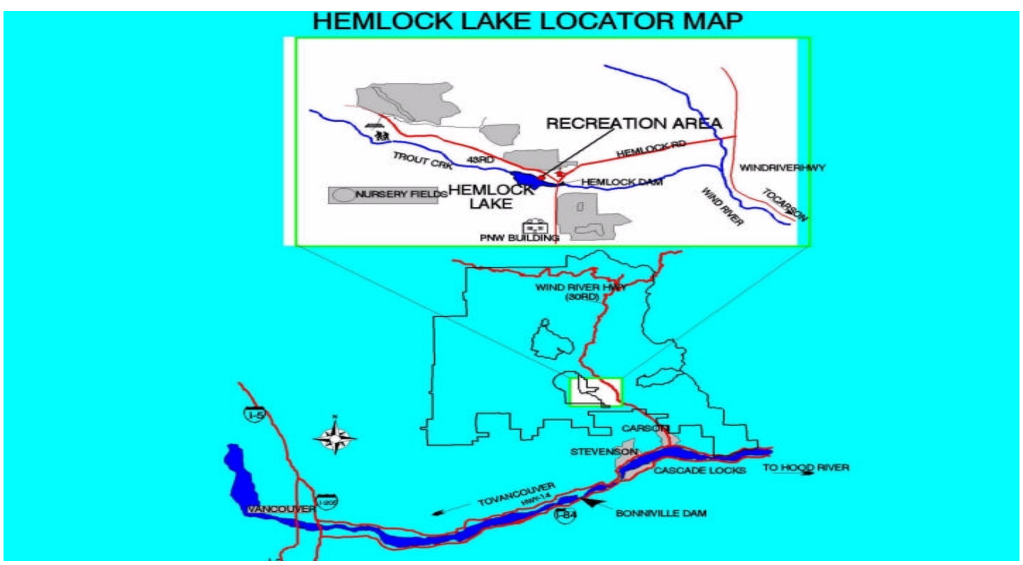

Figure 1. Location map of Hemlock Dam on Trout Creek. Skamania County Washington.

Project Area

The arched gravity concrete dam was originally constructed in 1935 (Figure 2A and 2B) by the Civilian Conservation Corps to generate hydroelectric power and in 1958 was remodeled to function as a means of irrigating the former Wind River Nursery. The total length of the dam is 183 feet and the spillway length is 112 feet. The height of the dam from the streambed to the crest of the spillway is 26 feet, with the north and south abutments rising six feet above the spillway crest. The radius across the face of the dam is 100 feet.

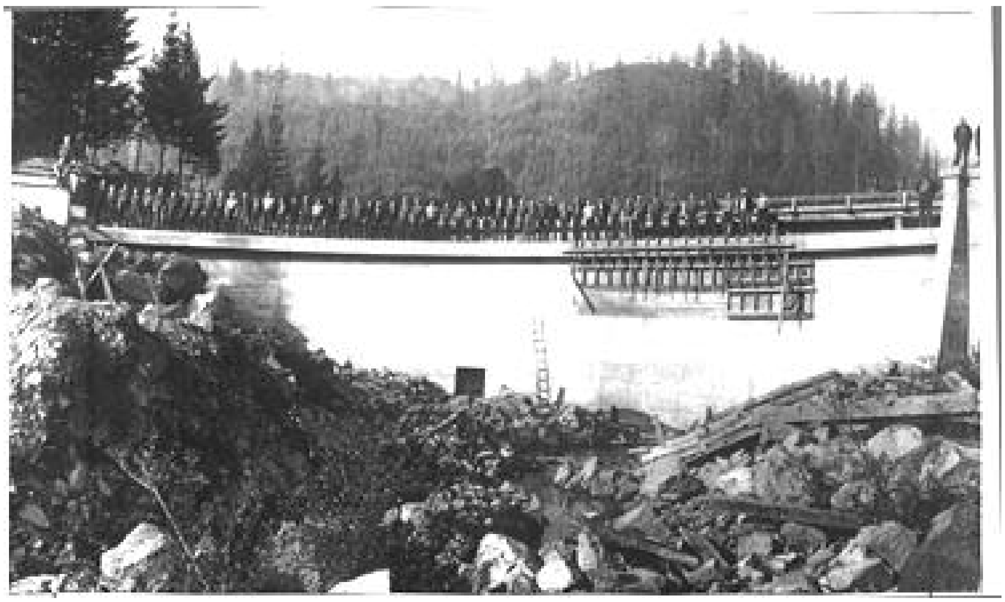

Figure 2A. 1936 photo of Civilian Conservation Corps constructed dam on Trout Creek. Skamania County, Washington.

Figure 2B. 1935 photo of the arched gravity dam under construction on Trout Creek. Skamania County, Washington.

A concrete fish ladder was constructed in 1936 making it one of the earliest fish ladders in the Northwest (Mack, 1995). It is a weir and stall style ladder designed with a variety of different chambers (Figure 3). The upper entrance of the fishway has a submerged 2'x2' opening located immediately behind a metal trashrack. Four chambers or control pools with slots are located at the head of the fishway. These chambers are approximately five feet in length, and five feet width. Below the eighth weir the fish ladder makes a turn of almost 180 degrees and the lower par of the fishway contains ten weirs. Behind each notched weir there is a chamber, which range in length from 5 to 11.2 feet.

Figure 3. A 1936 photo of fish ladder construction at Hemlock Dam on Trout Creek. Skamania County, Washington.

Study Objective

The objective of the project is to evaluate fish passage conditions at Hemlock dam and develop recommendations for restoration of upstream and downstream fish migration.

Methods

Study Design

A partnership was formed between the USDA Forest Service and Washington State University (WSU) School of Civil and Environmental Engineering to meet our objective. We followed a four-part process (Appendix A) summarized in the following:

1) **Assessment** - conduct a project area assessment of fish passage,
2) **Restoration Option Development** - assemble three options for restoring fish passage at Hemlock Dam,

3) **Project Work Plan** - develop a logistical plan necessary to implement each restoration option and,
4) **Economic Assessment -** conduct a benefit-cost analysis for each option

<u>Assessment</u>

A project area assessment was conducted to summarize known biological and physical components of Trout Creek and associated fish passage at Hemlock Dam. The assessment was based on existing data; HEC – RAS 2.2 and Fluent 5 analytical models; references to other published studies; comparison to regional, state or local standards; professional judgement; and/or empirical evidence (see Appendix A).

<u>Restoration Plan Development</u>

Three action options were designed to address a range of broad resource management objectives. These objectives were based on current and foreseeable future management issues at Hemlock Dam including the following:

Design criteria

Fish passage- develop options to restore salmonid habitat form and function and provide flow characteristics necessary for the safe and efficient upstream and downstream passage of adult and juvenile fish.

Recreation – develop options to retain traditional recreational opportunities at Hemlock Lake (e.g., tubing, swimming, and wading).

Irrigation – develop options to accommodate irrigation opportunities by retaining irrigation infrastructure and long-term water storage capacity.

Stream Channel, Fish Ladder and Fish Screen Reconstruction

Each of the options required a redesign of the stream channel. Due to the lack of pre-inundation measurements (or photos) it was necessary to rely on empirical evidence and/ or theoretical models to redesign the channel. The existing channel pattern developing in the forebay was mapped from 1996 air photos and compared to simulated channel patterns. Theoretical modeled relationships based on Brookes and Shields (1996) and Rosgen (1996) were used to generate channel geometry parameters (e.g. meander wavelength, amplitude, average bank to width ratio, radius of curvature, hydraulic radius, water surface slope, average sediment size, and flow top widths). Design criteria for reconfiguring the channel and ladder was dependent on steelhead performance capabilities based on Bell (1986), and NMFS (1995).

Project Work Plan

A written project work plan was prepared for each action option. The work plan prescribed project tasks, methods, and implementation schedule. Furthermore, the plan itemized project costs according to personnel, equipment, and materials. Equipment and construction values were based on Marshal and Swift (1998), and Kelley et al (1998).

Economic Benefit -Cost Assessment

A benefit cost analysis was developed to compare the value of each option. Dollar values for fish and recreational activities were modified from Meyer (1982), and Brown et al. (1980). The cost was analyzed at the two different time scales, initial and long-term (40 years). The initial cost reflects the implementation cost of proposed modifications. The short and long-term cost reflects the initial cost plus the expected maintenance and operation costs for each respective time period. Additionally, the long-term cost reflects the inevitable cost of removing the dam for those options where the dam removal is not prescribed in the initial cost.

Written documentation and Oral presentation

An interagency review board guided the project development (Appendix A). The board served as an advisory council to facilitate the exchange of ideas and represent agency guidelines. WSU made periodic presentations and released draft documentation (Appendix B) to update the board and generate comments

Results

Assessment

Hemlock Dam functions as a total barrier to migration barrier to fish. Steelhead trout (*Oncorhynchus mykiss*) are entirely dependent on a step-pool style fish ladder to ascend the 22-foot high dam on Trout Creek. This dam and associated fish ladder have been recognized a direct source of fish mortality (USDA, 1996) and a contributing factor for decline of native steelhead in the Lower Columbia River (Cowin, 1999; USDA, 1996).

The Trout Creek steelhead population has been on a precipitous decline since the late 1980's (Bair and Wieman 1995) (Figure 4) . Historically, Trout Creek is estimated to have produced 1,500 adult summer steelhead (Smith, 1995) or approximately one-half of the Wind River escapement. Nehlsen et al (1992) identified the Wind River winter and summer steelhead as stocks at a high and moderate risk of extinction respectively. In 1998 the US Fish and Wildlife Service (USFWS) declared the Lower Columbia steelhead (including the Wind River) as threatened for extinction.

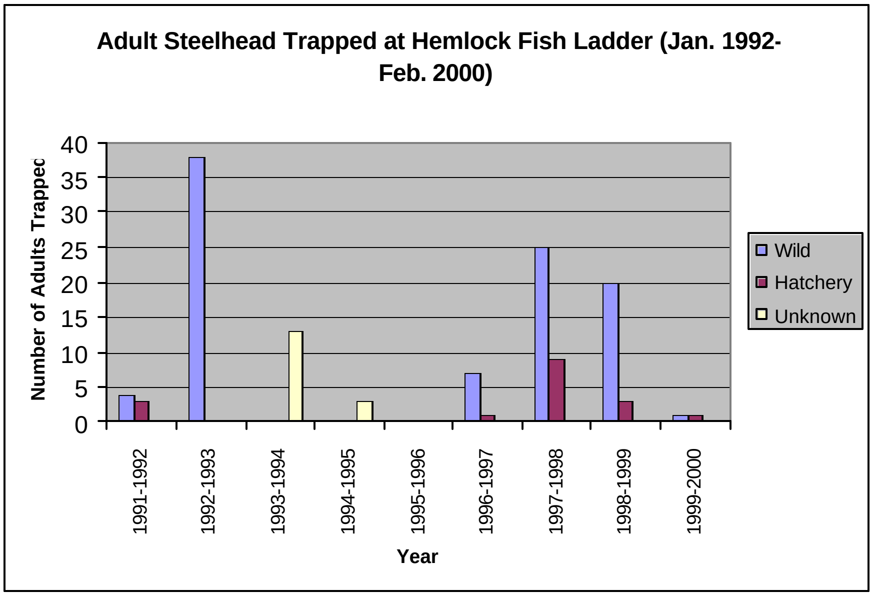

Figure 4. Steelhead escapement estimates from 1991-1999 based on adult trap results at a Hemlock Dam, Skamania County Washington.

Trout Creek has been the focus of many restoration scientists for nearly two decades. Fish biologists and engineers have identified a number of dam design features which may result in adversely impacting the safe and efficient passage of upstream and downstream migrants (Orsborn 1987, Bates 1995, Meyer 1995, Fredricks 1995, USDA 1996). Restoration efforts to improve attraction flow at the entrance of the fish ladder were implemented in 1995-1997 (Wieman and Rueda, 1995). Much data has been collected documenting steelhead life history and monitoring parameters affecting steelhead survival at Trout Creek (Connolly, 1995; USDA, 1996). The Trout Creek Flats area (RM 6.9-9.2) has been the focus of intensive restoration efforts over the past ten years. Project types include road decommissioning, riparian silviculture, and instream structural treatment.

The Hemlock Dam assessment specified several fish passage concerns. Our evaluation identified several key concerns that are direct source of mortality and/or impediments to safe and efficient fish passage of migrants including; inconsistent flow conditions, outdated ladder design, and ineffective dam fishway and trap operation. These concerns are summarized in Table 1.

Table 1. Assessment summary of fish passage concerns associated with Hemlock Dam, Skamania County Washington.

Category	Fish Passage Concern	Effect on Fish
Upstream passage	Low velocity/compound flow at entrance of fish ladder	Lack of attraction flow
Upstream passage	High velocity jet created from irrigation waste water system	False attraction flow
Upstream passage	Excessive small chambers and steep gradient ladder high velocity in ladder	Lack of resting water
Upstream passage	Inconsistent weir designs in fish ladder	Inconsistent jump signals
Upstream passage	Undersized trap box with mid spanning rib	Excessive turbulence and high
Upstream passage	Undersized water intake at upstream end of fish ladder	High velocity in trap and Poor regulation of flow
Upstream passage	Ineffective finger weir design	Injury/mortality and/or trap avoidance
Upstream and downstream	Ladder/trap confinement	Injury and/or mortality resulting from predation
Upstream and downstream	Human disturbance	Distracting /stressing fish
Downstream passage	Multiple low velocity flow patterns over dam/through screens and ladder	Insufficient attraction flow
Downstream passage	Excessive fall distance over dam	Injury or mortality resulting from impact
Downstream passage	High velocity water forced through small cracks	Injury or mortality resulting from impingement
Downstream passage	Excessive approach velocities through traveling screen	Injury or mortality resulting from impingement
Stream process and function	Shallow water in reservoir with low velocity	Migration barrier resulting from excessive warming
Stream process and function	Sediment /wood retention behind dam	Loss of organic, and gravels downstream
Stream process and function	Insufficient low flow stream discharge	Ineffective trap/ladder operation (see above)

Restoration Option Development

A summary of the options for dam restoration follows:

Option 1: The **No Action** option was proposed to serve as a control. This option is proposed to leave the existing structure in place and make no modifications to the dam.

Option 2 (A, B, C): The **Partial Dam Removal** option proposed to notch the dam at three different levels at 5,10,15 feet respectively). Additionally this option would analyze the development of a "recreation pond" and examine the retrofit of an irrigation system under each three notching levels. Options 2B, 2C proposed to eliminate the existing ladder and replace it with a reconstructed channel that would connect the current forebay to the spillway. (note: upon further analysis the 7 –ft. notch design shown to be a feasible).

Option 3: The **Full Dam Removal** option proposed to remove the existing dam structure in its entirety and reconstruct a natural stream channel. This option was expected to redesign the pumphouse water intake to draw surface water.

Option 4:The **Dam Upgrade** option leaves dam in place but redesign the fish passage system to meet current fish passage standards.

Table 2. Summary of Hemlock Dam restoration channel geometry design by Option. *Where*: *Alt 1* = No Action, *Alt 2A* = Partial dam removal with 5-foot notch and off-channel pond, *Alt 2B*= Partial dam removal with 10-foot notch, *Alt 2*C= Partial dam removal with 15-foot notch and off-channel pond *Alt 3* = Full Dam Removal, *Alt 4* = Upgrade Existing Dam Where *t* = dimensionless stress and *R* = Reynolds number.

Design Element	**Alt 2A**	**Alt 2B**	**Alt 2C**	**Alt 3**	**Alt 4**
water slope (%)	0.278	.556	.883	1.44	0.0005
channel width (ft)	60-68	60-80	58-90	80	NA
channel depth(ft)	4.4-5.2	4.0-5.0	3.5-4.5	3.1-4.5	NA
velocity (f/sec)	6.0-8.0	6.0-10	5.0-10.0	7.0-10.5	NA
t*	0.10	0.13	0.21	0.34	< .06
R	1326	1596	2653	4344	NA
LWD potential	low	low	mod	high	low
sinuosity	1.25	1.25	1.25	1.25	NA
amplitude (ft)	300	300	300	300	NA
wavelength (ft)	1200	1200	1200	1200	NA
radius of curve (ft)	225	225	225	225	NA

NOTE: t* of 0.06 or greater will transport sediment

Tasks associate with each restoration option

Tasks identified for each of the restoration options are summarized in Table 3.

Table 3. Summary of tasks prescribed for restoration options at Hemlock Dam. Skamania County, Washington.

Option 1 - No Action **1.** No tasks would be necessary to implement this option.
Option 2A - Partial Dam Removal w/ seven-foot notch • Five foot dam cut approximately 50 feet wide in face of dam • Create an off -channel pond to serve recreation/irrigation • Divert ladder approach water into side channel • Design and reconstruct the mainstem channel • Dredge and remove sediments • Redesign fish ladder with following features: • Pool space increased to provide resting water • Maximum flows regulated with wasting weir • Attraction flow at base of ladder redesigned • Standardize ladder orifices to provide consistent leap signals • Design may compromise integrity of the dam
Option 3 - Full Dam Removal • Fully remove the dam • Design the upstream channel • Redesign the irrigation system • Dredge and remove sediment from the reservoir
Option 4 - Upgrade Existing Dam • Redesign fish ladder with following features: • Pool space increased to provide resting water • Max. flows regulated with wasting weir • Attraction flow at base of ladder redesigned • Standardize ladder orifices to provide consistent leap signals • Redesign irrigation wastewater recycle line • Dredge and remove sediment from the reservoir

Economic Assessment

The results of the economic assessment are summarized in Table 4 below.

Table 4. Economic Assessment summary. Benefit cost comparison for four restoration proposals for Hemlock Dam, Skamania county , Washington. Where *Alt 1* = No Action, *Alt 2* = Partial dam removal with 5-foot notch and off-channel pond, *Alt 3* = Full Dam Removal, *Alt 4* = Upgrade Existing Dam. All values are in 1999 US dollar.

Option	Initial Cost ($)	Long Term Cost ($)	Total Cost ($)	Long-Term Benefit ($)	Benefit-Cost Ratio
1	0	2,335,857	2,335,857	118,944	0.05
2	1,935,466	1,822,297	3,757,763	4,056,108	1.08
3	1,091,297	240,000	1,331,297	4,562,250	3.43
4	1,048,833	3,266,137	4,314,970	4,496,856	1.04

Discussion

The objective of this study was to assess fish passage at Hemlock Dam and develop alternatives to restore passage. We established that there are a number of fish passage concerns associated with Hemlock Dam. Additionally, from the onset we realized there are multi-uses of the reservoir (e.g. recreation and irrigation) and we recognized the need to consider a range of restoration options. In response we established an array of design elements and resulting four options. Following is a summary table comparing the management issues for each restoration option.

Table 4. Comparison of restoration options based on management issues at Hemlock Dam. Skamania County, Washington. *Where*: *Option 1* = No Action, *Option 2* = Partial dam removal with 5-foot notch and off-channel pond, *Option 3* = Full Dam Removal, *Option 4* = Upgrade Existing Dam and *Y*= yes issue is addressed in given option, *N*= No issue is not addressed in given option

Restoration Concerns and Design Criteria	Optn 1 (Y/N)	Optn 2 (Y/N)	Optn 3 (Y/N)	Optn 4 (Y/N)
Recreational lake (water storage capacity)	Y	Y	N	Y
Irrigation system	Y	Y	Y	Y
Sedimentation	N	Y/N	Y	N
Water temperature	N	N	Y	N
Upstream fish passage	N	Y	Y	Y
Downstream fish passage	N	N	Y	N
Dam operation and maintenance	N	N	Y	N
Predation on fish	N	N	Y	N
Instream habitat (pools, LWD)	N	Y	Y	Y

Each restoration option addresses fish passage to a varying degree. There are distinct advantages and disadvantages for each. We considered it improbable that any level of dam restoration would achieve full recovery of fish as long as there are other sources of decline in and outside of the Trout Creek basin. In our best professional judgement we believe that there will be a range of fish recovery responses dependent on the degree of treatment at Hemlock Dam. The following table summarizes each restoration option and the expected biological result. Additionally, this table synthesizes economic data to generate a monitory value for each restoration option. A benefit cost ratio provides a standardized values to compare alternatives.

Table 5. Restoration Option Summary Table describes the tasks prescribed with each restoration option and the expected return of adult steelhead (STH) to upper Trout Creek. Skamania County, Washington. Where Option *1* = No Action, *Option 2* = Partial dam removal with 5-foot notch and off-channel pond, *Option 3* = Full Dam Removal, Option *4* = Upgrade Existing Dam.

Option No.	Short –Term Tasks	Fish Passage Issues Unresolved	Estm. STH Return in 15 years	Estm. STH Return in 40 years	Operation and Maintenance	Long-Term Tasks
1	None	Fish Ladder Fish Trap Drop mortality Temperature Sediment Balance Large Wood Impingement Predation	0	0	Fish Ladder Fish Trap Dam	Full Dam Removal
2	Notch Dam Channel Restoration Off Channel Pond New Fish Ladder New Irrigation Screen	*Temperature* *Sediment Balance*	480	650	*Fish Ladder* Fish Trap Dam Off Channel Pond	Full Dam Removal
3	Dam Removal Channel Restoration New Irrigation Intake	None	500	720	None	None
4	New Fish Ladder Dredge Lake New Irrigation Screen	Drop over Dam Temperature Sediment Balance Large Wood Impingement Predation	430	650	*Fish Ladder* Fish Trap Dam	Full Dam Removal

Option 1 – No Action option takes no measure to restore fish passage. As a result all the existing issues associated with the dam would persist (e.g. fish ladder, fish trap, drop mortality, temperature, sediment, balance, large wood, impingement, and predation). It is projected that this action would result in elimination of wild steelhead in 15 years and beyond.

The dam would continue to require daily operation and maintenance activities. In the long term (40 years) it is expected the dam would fail and full dam removal would be required.

Recreational activities associated with Hemlock Lake would remain in place in the short term; however, due to natural sedimentation processes the lake will continue to fill and diminish the traditional use of the lake. Lack of storage capacity would limit irrigation per the existing instream water right. Additional limitations with the system would persist due to a non-functional wastewater recycle line and pump system operating below standard.

The dam's structural integrity will continue to decline leading to the increased maintenance costs and eventual removal of the structure. The No Action option provides the lowest cost benefit (0.05) of all options proposed.

Table 6. Summary table for the No Action Option at Hemlock Dam. Skamania County, Washington.

Advantages

- Short term cost are low
- Recreation lake remains in short term
- Irrigation remains at current standard

Disadvantages

- Forebay (recreational lake) expected to continue to fill in over long term
- Water temperatures concerns continue to persist
- Adult upstream fish passage concerns not addressed
- Juvenile downstream fish passage concerns not addressed
- Dam maintenance and operation ongoing concern
    - Dam board management ongoing
    - Fish ladder maintenance ongoing
- Risk of juvenile impingement on dam surfaces
- Long term liability of aging dam

Irrigation system below standard and non-functional

- Recycle waterline not fully functional
- Limited water storage capacity will continue to diminish
- Dam removal necessary in the long term

Option 2 - The Partial Dam Removal option prescribes to notch a section of the dam, reconstruct a channel and off-channel pond, build a new fish ladder and irrigation screen. This study determined the only feasible notching scenario involves cutting a seven-foot deep section from the dam. Other notching levels were considered in this study but dropped from further consideration as a result of National Marine Fisheries Service (NMFS) design criteria restricting vertical leaps greater that one foot.

Installation of a new fish ladder should improve upstream passage. The notching will serve to pass downstream migrants along with sediment and large wood. Adult fish returns are projected to increase to 480 fish in the short term and 720 in the long term.

Option 2 requires the highest maintenance and operation costs due to the added complexity of managing an off channel pond and fish ladder features. The eminent cost of full dam removal is a contributing factor to long term costs.

The off channel pond would provide for traditional recreational opportunities and serve as a source of irrigation water. Lack of storage capacity would limit irrigation per the existing instream water right.

The benefit cost ratio (1.08) ranks second among alternatives proposed.

Table 7. Summary table for the Partial Dam Removal restoration option at Hemlock Dam. Skamania County, Washington.

Advantages • Improves downstream passage fish passage • Sediment transport (marginally) improved • Recreational pond and wetland developed • Some structure (LWD) reintroduced into forebay • Improves water temp concerns (marginally) • Upstream passage addressed
Disadvantages • Requires daily operation/maintenance (adjusting water levels, remove debris) • Pond contributes to temp concerns • Predation persists in fish ladder • Design may compromise integrity of the dam

Option 3 - The full dam removal option entirely removes the structure and restores a naturally free flowing river. This option fully addresses the negative impacts of fish passage at Hemlock Dam. This option optimizes passage conditions and is projected to increase adult returns to 500 fish in the short term and 720 fish in the long term. The aquatic system is expected to naturally function without any maintenance or operation requirements in the long term.

This option would return flows to the river and therefore reduce or modify the traditional recreational uses at Hemlock Dam. Decreased water storage would also impact the operation practices of the existing irrigation system. Lack of storage capacity would limit irrigation per the existing instream water right.

Full removal of the dam is expected to address all operational issues associated with fish passage at Hemlock Dam and would eliminate maintenance costs associated with the dam. Option 3 result in the highest benefit cost ratio (3.43) of all proposed restoration options.

Table 8. Summary table for the Full Dam Removal restoration option at Hemlock Dam. Skamania County, Washington.

Advantages • Upstream fish passage restored • Downstream fish passage restored • Sediment passage restored • Restoration of stream form and function • Routing sediment through system • Routing LWD through the system • No future dam liability • No long term dam maintenance and operation
Disadvantages • Eliminates existing forebay recreation play area • Reduces existing short term irrigation water storage capacity

Option 4 – Upgrade of the existing facilities involves dredging the lake and construction of a new fish ladder and irrigation screen. It is expected that issues associated with downstream fish passage would persist (eg. drop mortality and predation). Retaining the dam obstruction would also perpetuate water quality problems (eg. water temperature, sediment balance and large wood distribution).

There would be a net benefit to fish steelhead populations under this option. Upstream migration would improve as a result of replacing the fish ladder however downstream passage would not be addressed. Resulting short term and long term steelhead adult returns number 430 and 650 respectively.

Upgrading the existing facility will cost approximately $1.5 million. In the long term (40 years) it is expected the dam would fail and full dam removal would be required. The benefit cost ratio of this option is moderately low (1.04) ranking third among the four proposals.

Table 9. Summary table for the Upgrade Existing Dam restoration option at Hemlock Dam. Skamania County, Washington

Advantages • Upstream migration improved • Recreational lake remains status quo in short term • Irrigation system remains status quo in short term
Disadvantages • Dam related temperature concerns persist • Sediment transport not addressed • Dredging is a short-term fix • Downstream passage not addressed • Poor approach velocities • Drop mortality/injury persists • Impingement persists • Daily maintenance/operation persists • Liability of aging structure persists • Recreational lake diminished in long term • Irrigation system diminished in the long term

Conclusions

We concluded that:

1. The existing Hemlock Dam does not safely and efficiently pass fish upstream or downstream as a result of several limiting factors stemming from: insufficient attraction flow, drop mortality, impingement and predation. The dam also impedes natural function of the river and has adverse impacts on water temperature and sediment / LWD routing potential.

2. The three restoration options proposed address fish passage issues to a varying degree. However, the Full Dam Removal restoration option is the only proposal that completely removes the barriers to upstream and downstream fish migration.

3. The cost-benefit analysis clearly favors the Full Dam Removal option.

4. Hemlock Dam has a limited life span and eventually will need to be removed in the long term.

5. The No Action Option risks the potential elimination of steelhead in Trout Creek basin.

6. The option to notch the dam and construct an off channel pond is the most expensive proposal and results in the highest operation and maintenance costs.

Select References

American Society of Civil Engineers (ASCE). 1997. Guidelines for Retirement of Dams and Hydroeletricic Facilities. ASCE, New York, NY.

Bair, B., and K. Wieman. 1995. Trout Creek steelhead (Oncorhynchus mykiss), adult trap report. USDA Forest Service, Wind River Ranger District.

Bell, M. C. 1986. Fisheries handbook of engineering requirements and biological criteria. US Army Corps of Engineers, Portland, OR.

Brookes, A., and F.D. Shields. 1996. River channel restoration: Guiding principles for sustainable projects. John Wiley and Sons.

Connolly, P. J. 1995. The Wind River steelhead restoration project: With special emphasis on Trout Creek Basin. Prepared for: Columbia River Research Laboratory, National Biological Service, Cook, WA.

Kiley, M.D., and B.G. Moselle. 1998. 1998 National construction estimator. Craftsman Book Company, Carlsbad, CA.

Mack, C.A. 1995. Determination of “no adverse effect” Trout Creek fish passage restoration project. USDA Forest Service.

Meyer, P.A. 1982. Net economic values for salmon and steelhead for the Columbia River system. NOAA Technical Memorandum NMFS F/NWR-3. US Department of Commerce, NOAA, NMFS.

Nehlsen, W., Williams, J.E., and J. A. Lichatowich. 1992. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho and Washington. Fisheries 16(2):4-21.

Rosgen D.L. 1994. A classification of natural rivers. Cantena, Elsevier Science, B.V. Amsterdam 22:169-199.

Orsborn, J. F. 1987. A preliminary analysis of alternatives for improving fish passage at Trout Creek dam. 24pp.

USDA Forest Service. 1996. Wind River watershed analysis. 200pp.

Wieman, K., and H. Rueda. 1995. Trout Creek fish ladder restoration: Auxiliary water source and attraction flow installation, traveling screen modification, and pumphouse wastewater recycle system – project work plan- 1995. USDA Forest Service 7p.

Appendix A

Table A. Outline of US Forest Service and Washington State University agreement to assess fish passage and design restoration options at Hemlock Dam on Trout Creek. Skamania County, Washington.

1. Conduct a Project Area Assessment to summarize known biological and physical components of Trout Creek and associated fish passage at Hemlock Dam based on existing data; analytical models; references to other published studies; comparison to regional, state or local standards; professional; and/or empirical evidence.
    - 1.1. Compile and summarize existing biological information and data on Trout Creek, Hemlock Lake and associated fish species.
        - 1.1.1. Compare and contrast steelhead escapement in Trout Creek relative to the Wind River Basin according to WDFW and USFS data sources (1980-1998)
            - 1.1.1.1. Summarize the known population data, stock composition, distribution and migration timing of adult salmonids.
        - 1.1.2. Quantify steelhead smolt production.
            - 1.1.2.1. Summarize the known population, stock composition, distribution, age class, and timing of juvenile salmonid movement according to known sources.
        - 1.1.3. Address the potential impacts of stocking on the genetic integrity of the Trout Creek steelhead population.

    - 1.2. Compile and assess existing information and data on water quality/quantity and barriers affecting the free and efficient passage of fish at existing the Hemlock Dam fish bypass system.
        - 1.2.1. Summarize and assess juvenile bypass concerns including but not limited to the following (1.2.1.1 - 1.2.1.7):
            - 1.2.1.1. Effectiveness of passing low-flow downstream migrants through the fish ladder.
            - 1.2.1.2. Effectiveness of passing low flow downstream migrants over the dam by managing an orifice in dam stopboards.
                - 1.2.1.2.1. Effectiveness of juvenile bypass methods using surface overflow vs. a submerged bottom orifice.
                - 1.2.1.2.2. Effectiveness of juvenile bypass approach velocities at attracting fish to pass over the dam.
            - 1.2.1.3. Risk of fish mortality and/or injury due to striking the water or solid objects.
            - 1.2.1.4. Risk of mortality or injury due to excessive approach velocities at screened intake.

1.2.1.5. Risk of fish impingement on flashboards or other water control surfaces.
1.2.1.6. Impact of human induced stress or disturbance associated with public use.
1.2.1.7. Impact of fish-eating birds and aquatic mammals

1.2.2. Summarize and assess adult fish upstream bypass concerns including but not limited to the following (1.2.2.1 - 1.2.2.6):
1.2.2.1. Impact of false attraction flow associated with irrigation wastewater bypass system.
1.2.2.2. Effectiveness of artificial attraction flow at high and low flow conditions.
1.2.2.3. Effectiveness of weir configuration in fish ladder.
1.2.2.4. Effectiveness of resting water conditions in fish ladder.
1.2.2.5. Effectiveness of fish ladder flow conditions.
1.2.2.6. Potential for avoidance at the adult fish trap and effectiveness of control weir at retaining trapped adult steelhead.

1.2.3. Characterize the water temperature regime in Trout Creek.
1.2.3.1. Summarize and assess baseline water quality data (1990-1998) characterizing temperature-related factors limiting salmonid production and migration.

1.2.4. Quantify the stream discharge in Trout Creek.
1.2.4.1. Summarize and evaluate the USGS gage data.
1.2.4.2. Evaluate the effectiveness of adult and juvenile fish bypass system under normal low flow and normal high flow conditions.

1.2.5. Describe channel morphological features including but not limited to the following:
1.2.5.1. Characterize basin relief.
1.2.5.2. Characterize landforms and valley morphology.
1.2.5.3. Characterize Trout Creek basin sediment regime using existing studies, Hemlock Lake bythometric maps (1995), field sampling, and time sequence air photo interpretation.
1.2.5.3.1. Quantify known rates of sedimentation.
1.2.5.3.2. Characterize sediment routing process in the Trout Creek basin.
1.2.5.3.3. Quantify the volume of sediment and characterize the distribution of depositional features contained in the forebay.

2. Project proposal and option development.

2.1.1. Design four options ranging from total dam removal to a no action option. Design features of the action options should include the following components:

2.1.2. **Action Option One** will describe full dam removal with channel reconstruction. An additional suboption will describe an irrigation diversion retrofitted to the existing pumphouse water intake. Design criteria will include the following:

2.1.2.1. Remove the entire existing dam and fishway structure.

2.1.2.2. Demolish and dispose dam wreckage.

2.1.2.3. Excavate and dispose of depositional spoils.

2.1.2.4. Reconstruct Trout Creek channel.

2.1.2.4.1. Substrate size ranging from gravel to cobble.

2.1.2.4.2. Water surface slope less than two percent.

2.1.2.4.3. Instream flows providing year-round flow capable of transporting sediment and providing safe and efficient fish passage.

2.1.2.5. Install optional irrigation screened diversion connecting river surface water to existing irrigation intake.

2.1.3. **Action Option Two** will describe three scenarios of partial dam removal with an off-channel pond attachment and channel reconstruction. Design criteria will include the following:

2.1.3.1. Construct an off-channel pond

2.1.3.1.1. Locate in the proximity of existing day use area with water access from the existing reservoir north shoreline.

2.1.3.1.2. Storage capacity of approximately 60 - 80 acre-feet of water and a surface area of approximately 4 acres.

2.1.3.1.3. Average maximum depth approximately ten feet.

2.1.3.1.4. Adjustable water control structure regulating flow into pond and an outflow providing pond circulation.

2.1.3.2. Water diversion connecting pond to existing pumphouse intake.

2.1.3.3. Reconstruct Trout Creek channel.

2.1.3.3.1. Substrate ranging from gravel to cobble.

2.1.3.3.2. Water surface slope less than two percent.

2.1.3.3.3. Instream flows providing year-round flow capable of transporting sediment and providing safe and efficient fish passage.

2.1.3.4. Dam crest notched at three distinct depths ranging from approximately 5-15 feet below existing dam crest.

2.1.4. **Action Option Three** will reconstruct or improve the existing dam and fishway bringing it up to a state-of -the art standard. Design criteria will include the following:

2.1.4.1. Improve upstream bypass to address known concerns including but not limited to those items highlighted in the preceding assessment (1.2.2.1 - 1.2.2.6).

2.1.4.2. Improve downstream bypass to address known concerns including but not limited to those items addressed in the preceding assessment (1.2.1.1 - 1.2.1.7)

2.1.5. Produce conceptual, scaled, drawings for three action options.

2.1.5.1. Produce a conceptual plan view drawing from the provided project area contour map (1995). Mapped features will cover the wetted perimeter encompassing an area approximately 20 acres ranging from the dam spillway convergence zone to the upstream boundary near the mouth of Trout Creek at upstream extent of backwater influence zone.

2.1.6. Develop a written narrative describing project goals, objectives, desired future condition and proposed actions for each option.

2.1.7. Prepare a project work plan for the proposed action as determined by the FS on May 1, 1999 after delivery of the final evaluation by WSU.

2.1.7.1.1. Describe project tasks.

2.1.7.1.2. Describe methods to be used.

2.1.7.1.3. Describe implementation schedule and logistics.

2.1.7.1.4. Describe expected results.

2.2. Prepare an economic assessment for each action option

2.2.1. Prepare an itemized cost analysis to complete each action option.

2.2.1.1. Quantify project design and planning costs.

2.2.1.2. Quantify and describe implementation costs for each task.

2.2.1.2.1. Quantify and describe materials/supplies costs.

2.2.1.2.2. Describe equipment specifications (e.g. equipment size limitations, haul capacities, horsepower) and associated costs.

2.2.1.2.3. Describe labor skills needed and associated costs.

2.3. Prepare a costs-benefit analysis evaluating the expected expense and economic gain from the three action and one no action options.

3. End product and report specifications: The report shall include four or more options that address restoring fish passage ranging from for dam modification ranging from total dam removal to a no action option as described in Section 2 of this attachment.

3.1.1.1. One conceptual mapped drawing for each action option

3.1.1.2. One flood map displaying water extremes at 2, 5, 10 and 50-year flood reoccurrence interval for each option.

3.1.1.2.1. Mapped drawings should be produced in a recent version of auto cad (version 14 or newer).

3.1.1.2.2. Map contour interval should be no greater than one foot.

3.1.1.2.3. Drawings should be mapped at a scale of 1:600 scale.

3.1.1.2.4. Drawing should be mapped at a plan view.

3.1.1.3. One plan and profile sheet for each action option, including typical cross sections for free flowing stream .

3.1.1.4. One set of design calculations for each action option to include but not limited to:
3.1.1.4.1. Structures (e.g. weir, intake at pond, notched dam, fishway, etc.),
3.1.1.4.2. Newly constructed stream channel (e.g. streambed dimensions, particle size, geometry, gradient, sinuosity, etc.)
3.1.1.4.3. Pond and diversion channel and pumphouse intake connection.
3.1.1.4.4. Sediment measurements: total volume sediment in forebay and sediment to be excavated.
3.1.1.5. One set of detailed drawing of water control structures, dam, and fishway for each action option.
3.1.1.5.1. Detailed drawings should be produced in a recent version of auto cad (version 14 or newer) or compatible software.
3.1.1.5.2. Drawing perspective should be shown in a plan and profile view.
3.1.1.6. One written narrative describing Project Area Assessment and one Project Proposal per action option.
3.1.1.6.1. Narrative should be produced in Microsoft Word (Windows 95 version 7.0) or compatible word processing software.
3.1.1.6.2. Text shall be type written in New Times Roman size 10 font.

4. Project timeline, benchmarks and suggested relative proportion of project documentation.
4.1. This project will have three benchmark dates to provide for an opportunity for review and comment. To facilitate the efficient exchange of information WSU will provide twelve copies of deliverable items, one to each members of the FS review committee. These items shall be received no less than two full work days prior to the benchmark date. The FS will compile and deliver comments to WSU no later than four work days following the benchmark date.
4.1.1. **Benchmark 1: January 13, 1999** (or mutually agreed upon alternate date)
4.1.1.1. Deliver complete draft Project Area Assessment.
4.1.1.2. Deliver complete draft conceptual Project Area Map drawing (action options 1-3)
4.1.1.3. Presentation: WSU will provide a progress report and make an oral presentation to FS review committee on findings and provide an opportunity for review and comment on items 4.2.1.1 and 4.2.1.2.
4.1.2. **Benchmark 2: February 10, 1999** (or mutually agreed upon alternate date)

4.1.2.1. Deliver complete draft final Project Area Assessment
4.1.2.2. Deliver complete draft final conceptual Project Area Map drawing (action options 1-3).
4.1.2.3. Deliver complete draft detailed drawing of water control structures, dam, and fishway (action options 1-3).
4.1.2.4. Deliver complete draft economic assessment (action options 1-3).
4.1.2.5. Deliver complete draft Option Narratives (options 1-4).
4.1.2.6. WSU will provide a progress report to FS review committee on findings and provide an opportunity for review and comment on items 4.2.2.1, 4.2.2.2, 4.2.2.3, 4.2.2.4 and 4.2.2.5

4.1.3. **Benchmark 3: March 10, 1999** (or mutually agreed upon alternate date)

4.1.3.1. Deliver complete draft final conceptual Project Area Map drawing (option 1-3) .
4.1.3.2. Deliver complete draft final economic assessment (action options 1-3).
4.1.3.3. Deliver complete draft final detailed drawing of , water control structures, dam and fishway drawings (action options 1-3).
4.1.3.4. Deliver complete draft final Option Narratives (options 1-3).
4.1.3.5. Presentation: WSU will provide a progress report and make an oral presentation to FS review committee on findings and provide an opportunity for review and comment on items 4.2.3.1, 4.2.3.2, 4.2.3.3, and 4.2.3.4.
4.1.3.6. Presentation: FS will make presentation to WSU Hydraulics class.

4.1.4. Benchmark 4: April 1, 1999 (or mutually agreed upon alternate date)

4.1.4.1. Deliver final Project Area Assessment.
4.1.4.2. Deliver final Option Narratives (options 1-4).
4.1.4.3. Deliver final Conceptual Project Area Map drawing (options 1-4).
4.1.4.4. Deliver final detailed drawing of dam, water control, and fishway drawings (options 1-4).
4.1.4.5. Deliver final economic assessment (options 1-4).
4.1.4.6. Presentation: WSU will provide a final report and make oral presentation to the review committee on items 4.2.4.1, 4.2.4.2, 4.2.4.3, 4.2.4.4 and 4.2.4.5

4.1.5. **Benchmark 5: May 1, 1999** (or mutually agreed upon alternate date)

4.1.5.1. FS will deliver written notice of proposed action to WSU

4.1.6. **Benchmark 6: June 10, 1999** (or mutually agreed upon alternate date)

4.1.6.1. Deliver complete Project Work Plan described in 2.1.7 for the proposed action.

4.2. Suggested relative proportion of project documentation *(percent finished document allocated to given task)*

4.2.1. Project Area Assessment (*15*%)

4.2.2. Conceptual Project Area Map drawing development and design (action options 1-3) *(30%)*

4.2.3. Detailed drawings: water control structures, dam and fishway (action options 1-3) *(25%)*

4.2.4. Proposal Option Narratives (action option 1-3) (*25%)*

4.2.5. Economic assessment (action option 1-3) *(5%)*

5. Resources to be provided by cooperative partners.

5.1. FS products contributed to the project should include but are not limited to the following: *(approximate value of product provided)*

5.1.1. Hemlock Dam Evaluation, Washington State University (Orsborn 1984)

5.1.2. Hemlock Dam Inspection Report, Gifford Pinchot National Forest (DeJong 1995) *($300)*

5.1.3. Level II Stream Survey Reports, Gifford Pinchot National Forest (1995) *($6,000)*

5.1.4. Hemlock Lake bythometric maps (auto cad) (1995) *($3,500*)

5.1.5. Hemlock Dam architectural drawings (1935) (*$3,000*)

5.1.6. Hemlock Dam and fish ladder restoration drawings (1995) *($600)*

5.1.7. Steelhead smolt trapping results (1995-1998) *($5,000*)

5.1.8. Hemlock Lake Sediment Assessment (Seefelt 1986) *($2,000)*

5.1.9. Baseline water quality monitoring results (1990-1998)

5.1.10. Wind River Watershed Analysis (1995) *($10,000)*

5.1.11. USGS Trout Creek discharge data (1945-1949 and 1995-1998)

5.1.12. Sediment core sample and cross section mapping (1977) (pending availability)

5.1.13. Low elevation aerial photo sequence (1996) *($1,000)*

5.1.14. Historic aerial photo sequence (pending availability)

5.1.15. Hemlock Dam Cultural Resource Report (Mack 1996) *($2,000)*

5.2. WSU products contributed to the project should include but are not limited to the following: *(approximate value of product provided)*

5.2.1. Project Area Assessment *($8,800)*

5.2.2. Project Proposal Narratives *($12,000)*

5.2.3. Conceptual Project Area Map and detail drawing *($22,000)*

5.2.4. Detailed drawing of: dam, water control, and fishway drawings *($14,000)*

5.2.5. Economic assessment *($7,000)*

Appendix B

List of Participants in the Planning Process

Hemlock Dam Restoration Assessment and Restoration

Table B: List of Attendees at Hemlock Dam Fish Passage Evaluation and Restoration Proposal WSU Presentation. *Where*: #1 = Jan 15, 1999 #2 = Feb 22, 1999 and #3 = May 20 1999

Name	Affiliation	City	State	Resource Specialty	In Attendance (Y/N)		
					#1	#2	#3
Michael Barber	WSU	Pullman	WA	Engineer	Y	Y	Y
Ted Perkins	WSU	Pullman	WA	Engineer	Y	Y	Y
Ken Wieman	USFS	Carson	WA	Fish Bio	Y	Y	Y
Brian Bair	USFS	Carson	WA	Fish Bio	Y	N	Y
Julie Knutson	USFS	Carson	WA	Planning	N	N	Y
Mary Bean	USFS	Trout Lake	WA	Recreation	N	N	N
Woody Starr	USFS	Vancouver	WA	Engineering	Y	N	N
Helen Rueda	USFS	Vancouver	WA	Engineering	N	N	N
Dan Shively	USFS	Vancouver	WA	Fish Bio	Y	Y	Y
Al Matecko	USFS	Vancouver	WA	Administration	Y	N	Y
Earl Ford	USFS	Vancouver	WA	Administration	Y	N	Y
Bob Yoder	USFS	Vancouver	WA	Administration	Y	Y	N
Mary Gibson	USFS	Vancouver	WA	Administration	Y	Y	Y
Neil Oliver	USFS	Vancouver	WA	Engineering	Y	N	Y
Vicky Maggiora	USFS	Vancouver	WA	Lands and Minerals	Y	Y	Y
Pat Connolly	CRRL	Cook	WA	Fish Bio	Y	N	Y
Ruth Tracy	USFS	Vancouver	WA	Hydrology	N	N	Y
Ian Jezoreck	CRRL	Cook	WA	Fish Bio	Y	Y	N
Paul Ward	YIN	Toppenish	WA	Fish Bio	Y	N	N
Lee Carlson	YIN	Toppenish	WA	Administration	N	N	Y
John Baugher	BPA	Portland	OR	Administration	Y	Y	N
Tim Cummings	USFWS	Vancouver	WA	Fish Bio	Y	Y	Y
Ed Myer	NMFS	Portland	OR	Engineering	N	Y	N
Dave Heller	USFS	Portland	OR	Administration	N	N	Y
Dave Porter	USFS	Vancouver	WA	Rec Planning	N	N	Y
Harpreet Sandhu	Skam County	Stevenson	WA	Rural Planning	Y	Y	Y
Al McKee	Skam County	Stevenson	WA	Administration	Y	Y	Y
Dan Rawding	WDFW	White Salmon	WA	Fish Bio	Y	N	Y

Appendix C

Option 2 – Partial Dam Removal

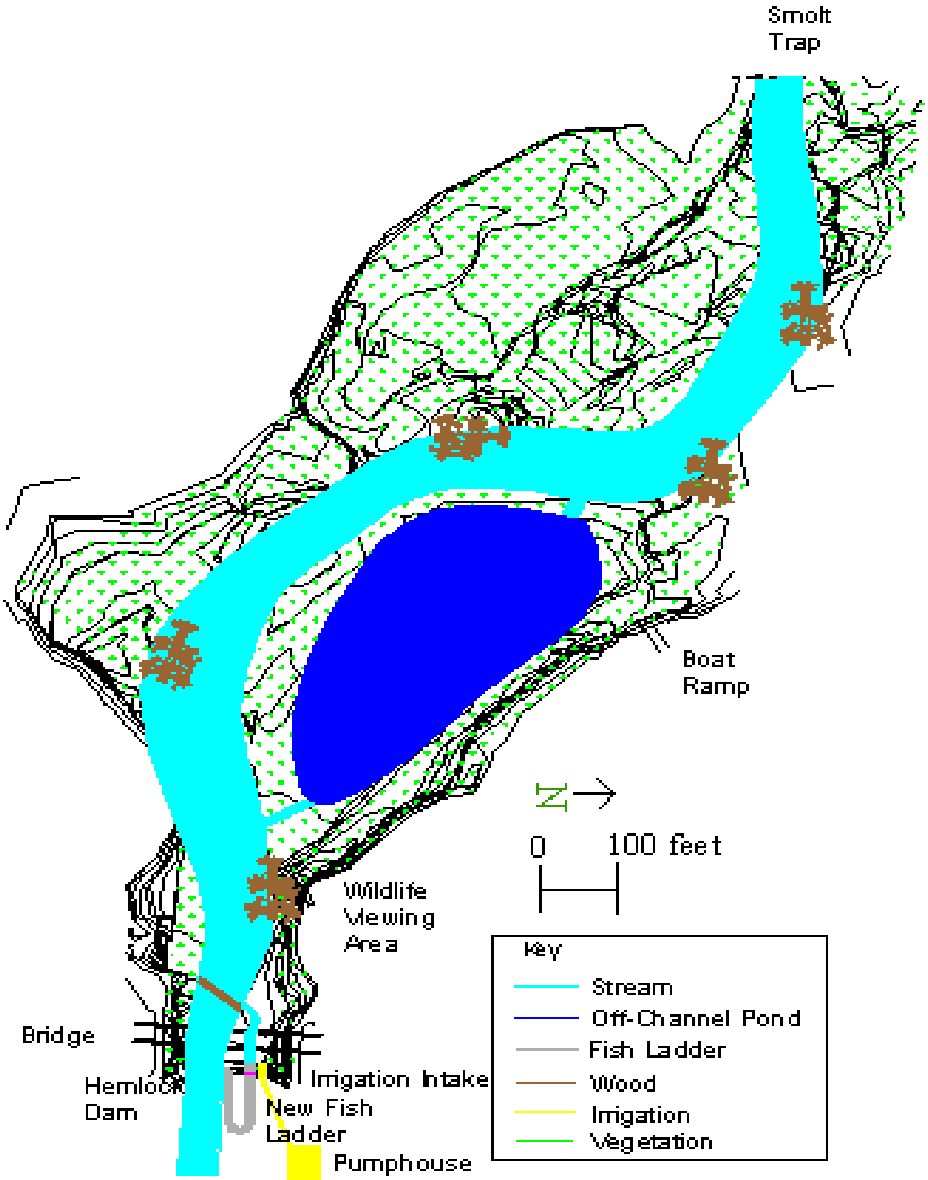

Figure C. Conceptual drawing of Option 2 – Partial dam removal proposes to notch the dam, replace the fish ladder, redesign irrigation system wastewater system, reconstruct the channel and add an off channel pond at Hemlock Dam on Trout Creek. Skamania County, Washington.

Appendix D

Option 3 – Partial Dam Removal

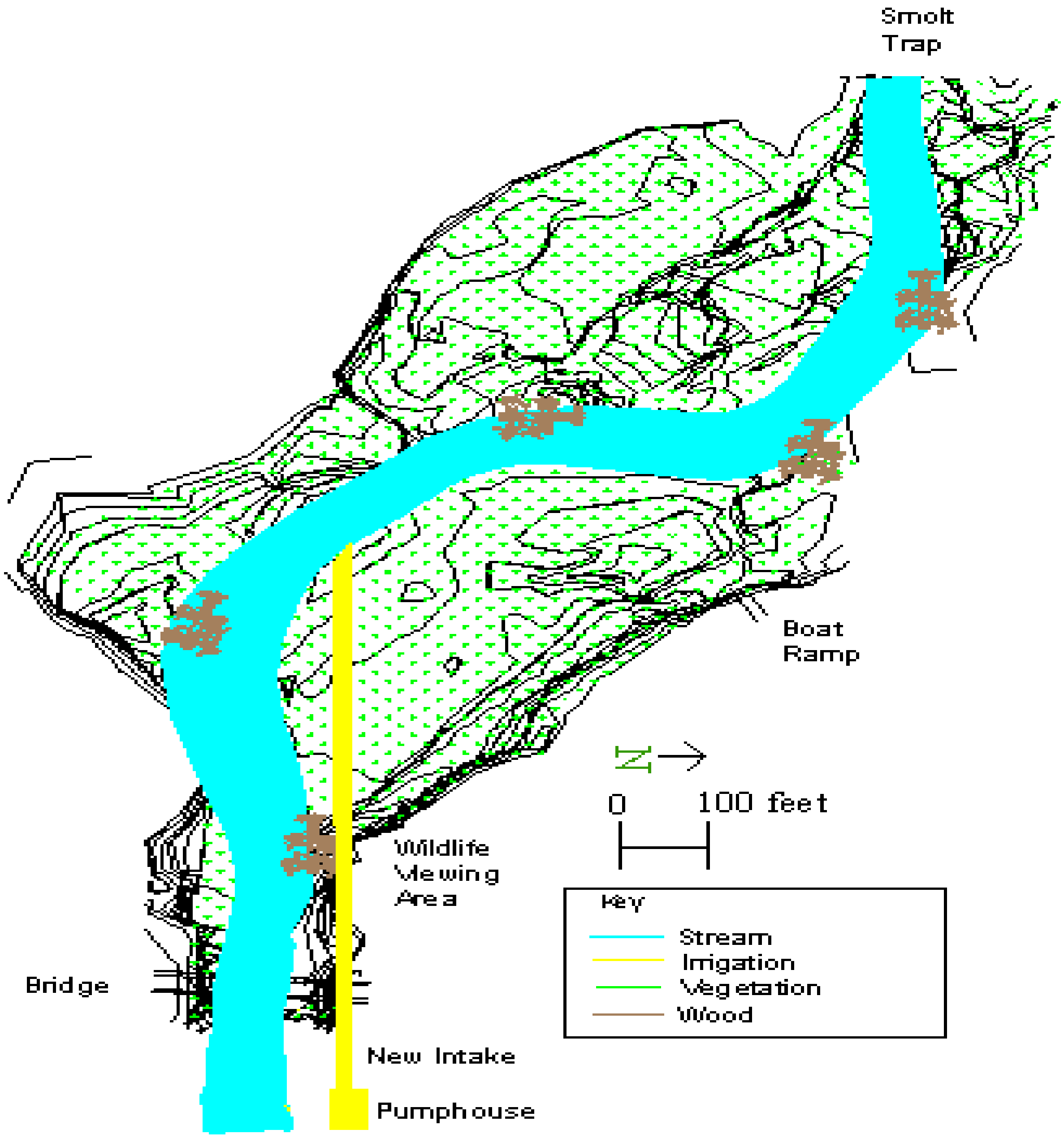

Figure D. Conceptual drawing of Option 3 – Full dam removal proposes to remove the dam and fish ladder, redesign irrigation system wastewater system and reconstruct the channel at Hemlock Dam Trout Creek at Hemlock Dam. Skamania County, Washington.

Appendix E

Option 4 – Upgrade Existing Facility

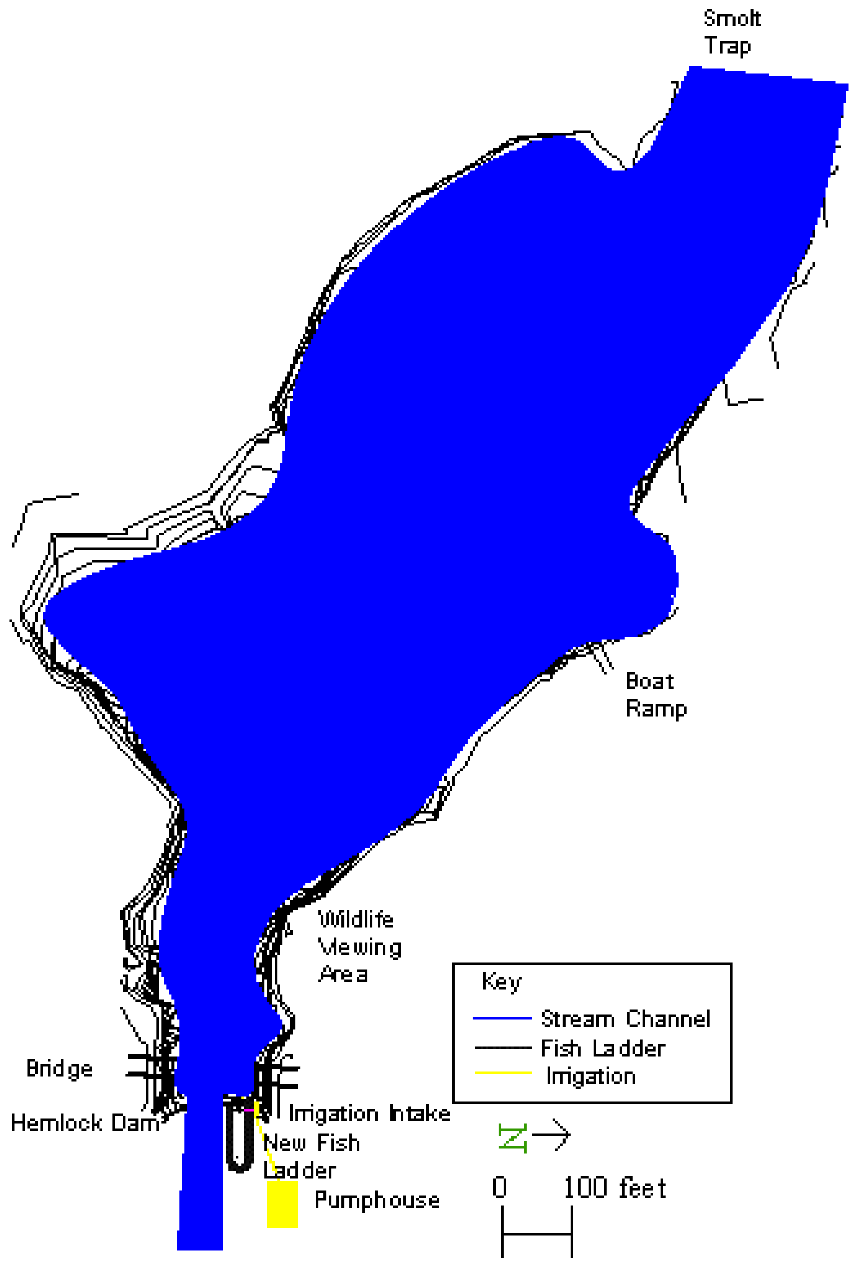

Figure E. Conceptual drawing of Option 4 – Upgrade existing facility proposes to redesigns the fish ladder and irrigation wastewater system and to dredge the reservoir at Hemlock Dam Trout Creek at Hemlock Dam. Skamania County, Washington.

Appendix F

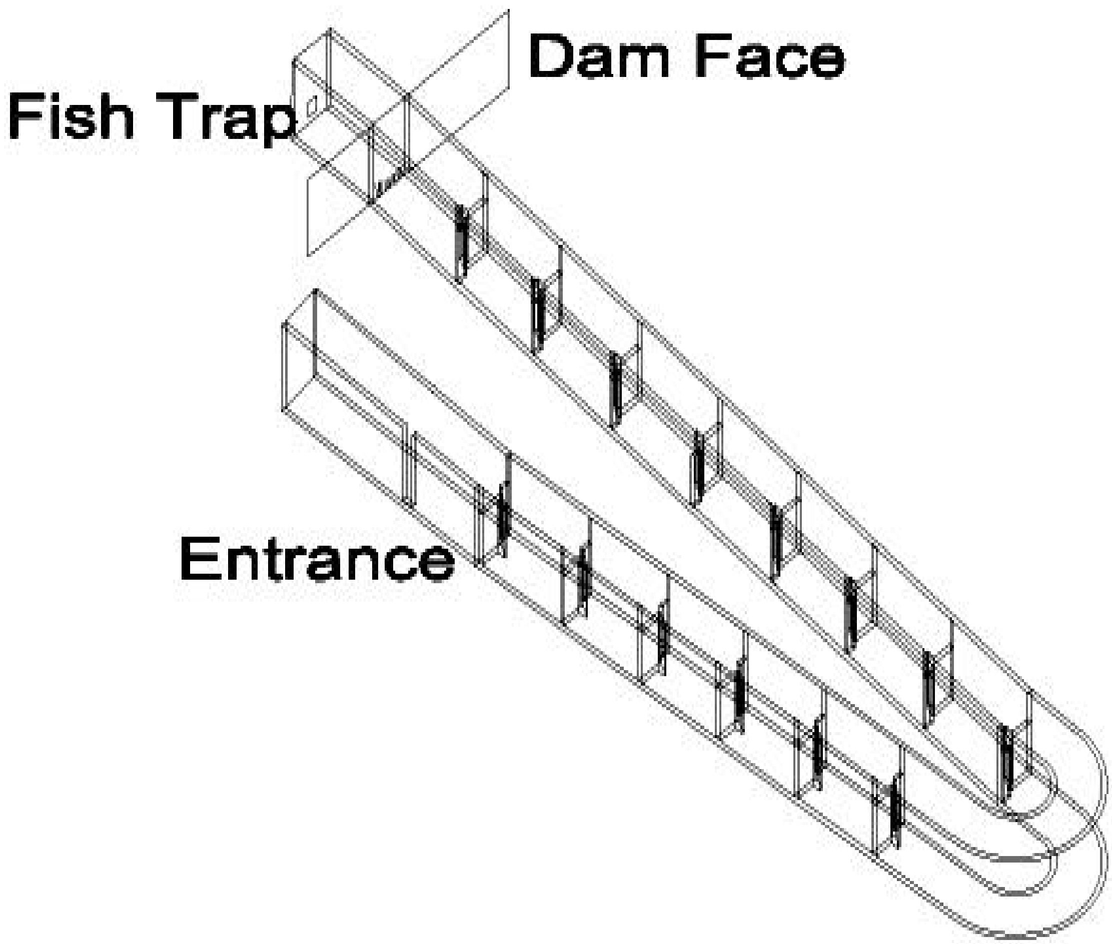

Figure F. Conceptual drawing of redesigned fish ladder on Trout Creek at Hemlock Dam. Skamania County, Washington.